Evaluation of zirconia-based posterior single crowns supported by zirconia implants: preliminary results of a prospective multicenter study

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Abstract: OBJECTIVE The aim of this uncontrolled prospective multicenter study was to determine the success and survival rate of posterior single crowns composed of zirconia frameworks hand-layered with a leucite-reinforced feldspathic ceramic supported by one-piece zirconia oral implants. MATERIAL AND METHODS In two centers, sixty patients received 71 zirconia oral implants. To obtain a clear indication of posterior implant-supported single crowns (ISSCs), 14 patients (25 implants) were excluded from the analysis (11 bridges, three anterior crowns). The remaining patients were provided with single implants in posterior regions. As one patient lost his implant and another refused further participation after final prosthesis insertion, 44 ISSCs/patients (19 females, 25 males) were available for evaluation. Of these patients, all were seen at prosthetic delivery and the 6- and 12-month follow-up appointments. Evaluations were performed using modified United States Public Health Service (USPHS) criteria. Restorations within Alpha and Bravo ratings were regarded as success. This included minor chippings, a slight roughness, slightly soundable restoration margins and minimal contour deficiencies. In case of more distinct defects that could, however, be repaired to a clinically acceptable level, restorations were regarded as surviving. Kaplan-Meier plots and log-rank tests were used for the success/survival analyses and the calculation of potential group differences (gender, jaw and center). RESULTS After a mean observation period of 12.5 months (SD: 0.8 months), no ISSC had to be replaced, resulting in a Kaplan-Meier survival rate of 100%. The Kaplan-Meier success rate was 90.9% (one major chipping, one obvious roughness, one significant crevice and one pronounced over-contouring). Minor chippings and occlusal roughness were frequent complications. No significantly different survival/success rates could be observed between the mentioned groups. CONCLUSION The frequent incidence of minor chippings suggests a high technique sensitivity when providing zirconia implants with veneered zirconia-based crowns questioning its suitability for this indication.

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Evaluation of zirconia-based posterior single crowns supported by zirconia implants: Preliminary results of a prospective multicenter study

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Abstract

Objective: The aim of this uncontrolled prospective multicenter study was to determine the success and survival rate of posterior single crowns composed of zirconia frameworks hand-layered with a leucite reinforced feldspathic ceramic supported by one-piece zirconia oral implants.

Material and Methods: In two centers, sixty patients received 71 zirconia oral implants. To obtain a clear indication of posterior implant-supported single crowns (ISSCs), 14 patients (25 implants) were excluded from the analysis (11 bridges, 3 anterior crowns). The remaining patients were provided with single implants in posterior regions. Since one patient lost his implant and another refused further participation after final prosthesis insertion, 44 ISSCs/patients (19 females, 25 males) were available for evaluation. Of these patients, all were seen at prosthetic delivery and the 6- and 12-month follow-up appointments. Evaluations were performed using modified United States Public Health Service (USPHS) criteria. Restorations within Alpha and Bravo ratings were regarded as success. This included minor chippings, a slight roughness, slightly soundable restoration margins and minimal contour deficiencies. In case of more distinct defects that could, however, be repaired to a clinically acceptable level, restorations were regarded as surviving. Kaplan-Meier plots and log-rank tests were used for the success/survival analyses and the calculation of potential group differences (gender, jaw and center).

Results: After a mean observation period of 12.5 months (SD: 0.8 months) no ISSC had to be replaced, resulting in a Kaplan-Meier survival rate of 100%. The Kaplan-Meier success rate was 90.9% (one major chipping, one obvious roughness, one significant crevice and one pronounced over-contouring). Minor chippings and occlusal roughness were frequent complications. No significantly different survival/success rates could be observed between the mentioned groups.

Conclusion: The frequent incidence of minor chippings suggests a high technique sensitivity when providing zirconia implants with veneered zirconia based crowns questioning its suitability for this indication.

(300 words)

Introduction

The outcome of dental implant therapy improves continuously and demonstrated to be a well-established treatment option for the support of fixed dental prostheses (Pjetursson et al. 2014). When searching an alternative to the present "gold standard" of titanium implants, e. g. for patients opposing metals, implants made of zirconium dioxide might be the first choice (Osman & Swain 2015). Zirconia dental implants are mostly available in a single piece consisting of an endosseous part, a prefabricated abutment and a transmucosal profile lying in between. Thus, the restoration needs to be cemented to the potentially intraoral individualized abutment and is, therefore, of a comparable design known from tooth-supported restorations. In a "metal free" treatment concept, not only the implant itself but also the implant-supported restoration needs to be fabricated of ceramic materials. To date, it seems that there is still the need of a supporting framework when replacing missing teeth. Again, zirconium dioxide, mostly available as yttrium stabilized tetragonal zirconia polycrystal (Y-TZP), proved to be a reliable core material for the manufacturing of fixed bi-layered all-ceramic implant-supported restorations (Larsson & Wennerberg 2014). Zirconium dioxide has mechanical properties nearly comparable to those of metals, and a color similar to that of teeth (Piconi & Maccauro 1999). It has higher flexural strength and fracture toughness than other ceramic materials applied for the manufacturing of all-ceramic FDPs like reinforced glass-ceramics or glass-infiltrated alumina (Tinschert et al. 2000). However, zirconia-based bi-layer restorations showed a remarkable incidence of veneering material fractures with a higher chipping susceptibility of implant-supported compared to tooth-supported single crowns and fixed dental prostheses (Larsson & Wennerberg 2014, Le et al. 2015, Spies et al. 2015b, Spies et al. 2015c).

Several approaches for an improved fracture resistance of the veneering ceramic of all-ceramic restorations were proposed. This mostly included the presence of leucite crystals in zirconia veneering ceramics (Choi et al. 2011b), a homogenous layer thickness (Kamio et al. 2014, Silva et al. 2011), a harmonization of the thermal expansion of the core and veneering material (Fischer et al. 2007) or a long-term cooling procedure due to the low thermal conductivity of zirconia (Choi et al. 2011a).

Therefore, the aim of the present evaluation was to consider the above mentioned suggestions for improvement and determine the success and survival rate of implant-supported single crowns comprising CAD/CAM-fabricated zirconia frameworks hand-layered with a leucite reinforced feldspathic ceramic.

Materials and Methods

Study design

The present study is a prospective cohort investigation conducted as a one arm clinical trial including two centers: Medical Center – University of Freiburg, Center for Dental Medicine, Department of Prosthetic Dentistry, Freiburg, Germany and Clinic for Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Switzerland. All procedures and materials were approved by the local ethical committees (Ethics committee of the Canton of Zurich [StV 08/10] and of the Medical Center Freiburg [241/08]). Informed consent was obtained from all patients prior to the start of the study. This research was designed and performed considering the STROBE Statement for cohort studies (Strengthening the reporting of observational studies in epidemiology; http://www.strobe-statement.org).

Participants

In the present study, 60 patients in need of an implant-supported single tooth restoration or a three-unit fixed dental prosthesis (FDP) in the upper or lower jaw have been recruited, provided they fulfill the following inclusion criteria: Age of 20-70 years, good health status and compliance, need of an implant-supported restoration, sufficient bone volume in the area of interest and a stable occlusal relationship without signs of pronounced bruxism. Drug abuse, smoking (>10 cigarettes/day) and severe bruxism were reasons for exclusion. The screening for bruxism was performed clinically considering pronounced/anomalous signs of attrition, muscle pain and the presence of temporomandibular disorders as detectable sequelae. The supporting cylindrical and screw-type single-piece zirconia implants (ceramic.implant prototype; vitaclinical, VITA Zahnfabrik; Bad Säckingen, Germany) were provided in lengths of 8, 10, 12 and 14 mm and diameters of 4.0, 4.5 and 5.5 mm. The zirconia material was composed of 93% ZrO_2, 5% Y_2O_3, 1.9% HfO_2 and 0.1% Al_2O_3 by weight. The prototype abutment was designed conically, 5 mm of height and provided circumferential flattenings and a horizontal notch as antirotational/retentive elements. The process of surgery and the criteria for evaluating the tissue-response were already described in a separate publication (Jung et al. 2015). In order to obtain a clear indication for the present evaluation of posterior single crowns, 14 patients restored with 11 FDPs and 3 anterior crowns were excluded from the analysis. In addition, feldspathic veneered FDPs on zirconia implants do not conform to the manufacturer's recommendation. Of the 46 patients with posterior implant-supported single crowns (ISSCs), one lost his implant 5 weeks after implant

insertion and another refused to participate in further follow-ups after insertion of the final crown for unknown reasons. For evaluation of the prosthesis, both were regarded as drop-outs. Therefore, 44 patients (19 females, 25 males) provided with 44 posterior ISSCs located in the region of a former premolar (n=17) or molar (n=27) remained for evaluations and analyses (Tab. 1). Of these restorations, 29 were opposed by solely natural teeth, nine by restored teeth or a combination of a restored and a natural tooth, three by tooth-supported FDPs, two by implant-supported FDPs and one by a tooth-retained removable dental prosthesis.

Restoration manufacturing and clinical procedures

The implants were immediately temporized with prefabricated provisional reconstructions made of PMMA. The provisional reconstructions had slight occlusal contacts (shimstock foil of 8 µm thickness could be pulled through) but care was taken to avoid excessive occlusal and lateral loads. Implants placed in the mandible have been reconstructed definitively not before 2 months post-surgery, while implants placed in the maxilla have been reconstructed not before 4 months after implant insertion. Final impressions were taken using impressions caps (Fig. 1) and a polyether material (Impregum; 3M Espe, Seefeld, Germany) with a closed custom tray. An interocclusal registration was taken in the area of interest using a silicone based and scannable bite-registration material (Twinduo scan; picodent, Wipperfürth, Germany). Class IV stone (dentona, Dortmund, Germany) was poured in the impression after the placement of a laboratory implant analogue and the final master casts as well as the bite-registrations were digitized (Fig. 2; inEos, Serial number: 41318; Sirona, Bensheim, Germany). The frameworks were designed using the latest software package of the manufacturing device (Cerec inLab®, V3.65 till 5/18/2011 and V3.86 from 5/19/2011). The finally designed frameworks were wet-grinded out of partially pre-sintered zirconia blanks (inLab® MC XL, Sirona, Serial number: 112625; In-Ceram YZ, VITA Zahnfabrik), manually finalized, dried and sintered (ZYrcomat®, VITA Zahnfabrik, Serial number: 520040273) according to the manufacturer's instructions (VITA In-Ceram YZ manual published June 2006). Subsequently, the frameworks were seated to the master cast validating a sufficient anatomical support to realize a uniform layer thickness of the veneering ceramic. Furthermore, the frameworks were checked intraorally for their accuracy of fit. After a satisfying try-in, the frameworks were hand-layered according to the manufacturer's instructions (Veneering ceramic: VM9, VITA Zahnfabrik; Sintering furnace: Vacumat 6000M, VITA Zahnfabrik, Serial number: 1320090454; VITA VM9 manual published April

2009). Restorations were intraorally validated regarding the marginal fit and the occlusal and proximal contact points and both centric and dynamic occlusion were controlled and adjusted if necessary. In case of adjustments, ground areas were re-polished in the laboratory. Subsequently, the provisional restorations were removed and abutments cleaned from the temporary luting cement with a polishing brush and an oil- and fluoride-free cleaning paste. Shade, fit and occlusion of the final restoration was controlled in the next step. Finally, the restorations were adhesively cemented using a dual-curing resin cement (RelyX Unicem Aplicap; 3M Espe). Centric and dynamic occlusion were controlled (12µm occlusion foil, 8µm shimstock foil) both on the restoration and the residual dentition to avoid any excessive forces. In case of necessary re-adjustments, the restoration was again sent to the laboratory for re-polishing the ground areas. The chemical composition and some physical properties of the core and veneering ceramic are listed in table 2. An exemplary case is shown in figure 3.

Follow-up appointments

A final inspection was scheduled three days after the cementation of the definitive restorations. Follow-ups were performed 6 and 12 months after prosthesis insertion. Further follow-up will be performed after 24, 36, 48 and 60 months. In case of any noticeable alteration or adverse event, patients were asked to contact the departments. The follow-ups included a visual control of the restoration surfaces with 4-5 fold magnification as well as a control of occlusion and articulation. Impressions and clinical photographs of the restorations including adjacent teeth were taken at the time of cementation and at the follow-up examinations. Clinical complications were documented and the required treatment applied if necessary.

Survival and success rating

The restorations were evaluated according to modified United States Public Health Service (USPHS) criteria (Cvar & Ryge 2005). Five evaluation parameters were considered: framework fracture, chipping of the veneering ceramic, occlusal roughness, marginal integrity and contour of the restoration (Tab. 3). In general, restorations within a range of excellence were rated "Alpha", whereas clinical acceptable restorations showing minor deviations from the ideal were judged to be "Bravo". Restorations with clinically unacceptable defects that could be repaired to a clinically acceptable level through, for instance, polishing were rated "Charlie". In case of an unrepairable problem of clinical relevance, a restoration was rated "Delta". A restoration was regarded successful in absence of any "Charlie" or "Delta" rating,

whereas surviving restorations included "Charlie" ratings. With the occurrence of any "Delta" rating a restoration was judged to be a failure.

Statistical analyses

Sample size calculation (60 patients) was performed considering the expected bone resorption (known from the literature) and was, therefore, not primarily designed for the evaluation/analyses of the prosthetic restorations (Jung et al. 2015). Means, medians and standard deviations were computed for descriptive analyses of the data. Kaplan-Meier survival and success rates were calculated and graphically presented using plots. Moreover, log-rank tests were used to check for differences between the groups (gender, jaw and center). All calculations were performed with the statistical software STATA 13 (StataCorp LT, College Station, TX, USA). The probability level for statistical significance was set to $p < 0.05$.

Results

Status of follow-up

The final restorations were delivered between 04/2010 and 02/2012. The mean patient age at prosthetic delivery was 46.6 years (SD: 13.1 years, range: 25-69 years). All patients were seen at the one-year follow-up between 04/2011 and 03/2013 resulting in a mean observation time of 12.5 months (SD: 0.8 months).

Survival, success and chipping analyses

No ISSC had to be replaced, resulting in a Kaplan-Meier survival rate of 100% (Kaplan & Meier 1958). Based on the definition of success (Tab. 3) and the evaluations at prosthetic delivery and the follow-ups (Tab. 4), Kaplan-Meier success rates were calculated and presented as plots (Fig. 4, Tab. 5). The calculated Kaplan-Meier success rate was 90.9%. No framework fracture or loss of retention was observed. The performed log-rank tests revealed no statistically significant differences for the success curves regarding jaw ($p = 0.4996$), gender ($p = 0.7656$) and center ($p = 0.4301$).

Discussion

Based on the applied definitions for survival and success, the evaluated restoration method for a ceramic dental implant system revealed a high survival but reduced success rate after a short-term observation period of 12 months. However, it must be considered that two of these observations (over-contouring and marginal discrepancy) are not material-related. Non-success was based on one obvious roughness, on one extended veneer chipping, on one over-contouring and on one significant marginal discrepancy for the ISSCs.

There is only one directly comparable study available in the literature, prospectively evaluating zirconia-based implant-supported single crowns and three-unit fixed dental prostheses cemented to the abutments of one-piece zirconia oral implants (Spies et al. 2015b). However, Spies and colleagues mainly reported on the incidence of veneer fractures and did not apply extended criteria like provided by the USPHS. Therefore, the success rates reported in 2014 should rather be compared to the chipping-free outcome of the present study instead of the reported success rates including several other variables. After one year of observation, a success rate of 91.9 (57/62) could be observed for ISSCs fabricated of zirconia frameworks (Procera Zirconia, Nobel Biocare) veneered with a silicate ceramic veneering material (NobelRondo Zirconia, Nobel Biocare). These success rates seem to be slightly superior compared to the Kaplan-Meier chipping-free outcome of the present investigation after one year of observation (86.4%). However, in the mentioned study implant surgery served as baseline (compared to prosthetic delivery in the present investigation), resulting in a significantly shorter observation period of the restorations at the timepoint of the one-year follow up (prosthetic delivery was in average 2.8 months after implant installation in the maxilla and 4.4 month after implant installation in the mandible). Two years after implant surgery, remarkably reduced success rates of 80.6 (50/62) could be observed for the ISSCs (Spies et al. 2015b). Therefore, the chipping resistance of the currently evaluated all-ceramic bi-layer restorations seems to be slightly superior, although still not being satisfactorily. This marginal improvement might be owed to the superior flexural strength of the veneering ceramic used in the present study (Fischer et al. 2008) or to an improved fracture toughness of the veneering ceramic due to the presence of a stabilizing crystalline phase (Choi et al. 2011a, Choi et al. 2011b).

Except the above mentioned investigation on the restoration of ceramic dental implants, several other investigations on zirconia-based fixed restorations among others supported by

conventional two-piece titanium implants might be suitable for comparison (Dhima et al. 2014, Esquivel-Upshaw et al. 2014a, Esquivel-Upshaw et al. 2014b, Hosseini et al. 2013, Keough et al. 2011, Koenig et al. 2013, Kolgeci et al. 2014, Kollar et al. 2008, Konstantinidis et al. 2015, Larsson & Vult von Steyern 2010, Larsson & Vult Von Steyern 2013, Lee et al. 2015, Monaco et al. 2015, Nejatidanesh et al. 2015, Nothdurft & Pospiech 2009, Pozzi et al. 2015, Rammelsberg et al. 2013, Sagirkaya et al. 2012, Schwarz et al. 2012, Tartaglia et al. 2014, Worni et al. 2014). However, it is often reported on a mixture of indication ranges including both tooth- and implant-supported single- to multiple-unit restorations with only providing pooled survival and complication rates. When only considering the mostly comparable investigations (i.e. prospective evaluations on cemented zirconia-based and implant-supported single crowns), seven studies including ISSCs (Hosseini et al. 2011, Hosseini et al. 2013, Kollar et al. 2008, Lee et al. 2015, Nothdurft & Pospiech 2009, Sagirkaya et al. 2012, Tartaglia et al. 2014) are remaining for comparison. For two investigations (Kollar et al. 2008, Sagirkaya et al. 2012), the information to split the tooth- and implant-supported results had to be extracted from a literature review of Larsson and Wennerberg (2014) who contacted the corresponding authors in case of incomplete information. The results of the selected studies are heterogeneous: In some investigations no or very little (3.8%) technical complications after mean observation periods of 1-4 years could be observed (Hosseini et al. 2011, Hosseini et al. 2013, Sagirkaya et al. 2012, Tartaglia et al. 2014). However, other investigations reported on chipping rates as high as 7.5% after 6 months (Nothdurft & Pospiech 2009), a 86% chipping incidence after 4 years and a significantly higher susceptibility of zirconia-based bi-layered restorations compared to the metal-ceramic control group (Lee et al. 2015) or a chipping incidence of 12.5% after two years with a higher chipping susceptibility of zirconia-based ISSCs compared to tooth-supported zirconia-based single crowns (Kollar et al. 2008).

When comparing the results of different investigations, the application of different evaluation criteria like the ones provided by the United States Public Healthcare Service (USPHS) or the Californian Dental Association (CDA) hamper comparability. Especially regarding the documentation of veneer fractures, it is mostly distinguished between “minor” (to be polished) or “major” chippings, as done in the present investigation. The classification of small area chip-off fractures that can be corrected with small efforts as minor technical complication has also been suggested by a working group of the VIII European Workshop on Periodontology (Lang & Zitzmann 2012). However, unless specific criteria are proposed to

278 determine when a fractured surface should be polished or when it should be repaired,
279 significant variability will occur.

280 Besides chipping of the veneering, other factors like occlusal-roughness or marginal misfit
281 were contributing to non-success in the present investigation. In the majority of cases even a
282 major roughness can be polished and can therefore be considered reversible. However, it
283 could be shown that occlusal surface roughness affects the flexural strength of veneering
284 ceramics and might, therefore, be a precursor of upcoming fatigue (Fischer et al. 2003). Until
285 the appointment at which the roughness is detected and removed, opposing enamel or
286 restorative materials might be subject to an increased wear (Heintze et al. 2008, Saiki et al.
287 2014). Furthermore, a positive correlation between surface roughness and the amount of
288 Streptococcus mutans adhesion was observed (Al-Marzok & Al-Azzawi 2009). Since
289 roughness was solely located in occlusal areas, susceptibility for bacterial adhesion might be
290 of minor relevance. The observed difficulty of fabricating zirconia-based restorations without
291 visible or soundable marginal gap was also reported by Hosseini and co-workers (2011,
292 2013): In their clinical comparison of zirconia- and metal-ceramic ISSCs, the marginal
293 adaption of zirconia-based crowns were significantly less optimal. This might be owed to the
294 inaccuracies of early CAD-CAM technologies and, therefore, not representative for the
295 nowadays available systems.

296 Patients with severe bruxism were excluded from the present investigation, since
297 parafunctional habits represent a biologic cause that might be responsible for failure of the
298 veneer (Anusavice 2012). Bruxism is a repetitive jaw-muscle activity characterized by
299 clenching or grinding of the teeth and/or by bracing or thrusting of the mandible. It has two
300 distinct circadian manifestations: it can occur during sleep or during wakefulness (Lobbezoo
301 et al. 2013). It has been reported that the prevalence of bruxism is approximately 20% for
302 clenching and 6% for grinding (Schmitter et al. 2014). However, identification of bruxers is
303 challenging and the screening applied in this evaluation might have been insufficient for
304 proper diagnosis. A solely clinical evaluation is easily applicable for larger study populations,
305 but for example tooth wear as a proxy for bruxism suffers from its cumulative nature and
306 multiple differential diagnoses (Lobbezoo et al. 2013). Owed to the difficulty of proper
307 diagnosis and the circumstance of bruxism being considered as reason for exclusion in most
308 of the available studies, there is a lack of information about the effect of bruxism on the
309 incidence of technical failure (Schmitter et al. 2014). However, in some recent studies an
310 association between parafunction and failure was reported (Koenig et al. 2013, Monaco et al.

2015). In one of the mentioned investigations, several other parameters besides parafunctional activity like the presence of implants as support and a ceramic restoration as antagonist were shown to significantly influence veneer fracture (Koenig et al. 2013). Approximately one third of the restorations of the present investigation were opposed by at least one restored or artificial tooth, but no correlation between the type of antagonist and the occurrence of technical complications could be detected.

Conclusions

Considering the short-term observation period of one year, posterior bi-layered zirconia-based ISSCs supported by zirconia oral implants showed a 100% survival rate but a reduced success rate. A further incidence of the observed technical complications might result in the need of uneconomic replacements. Therefore, more data are necessary to completely understand the mechanism of surface deterioration of veneering ceramics used as occlusal faces in zirconia based posterior restorations on implants. Monolithic approaches (Spies et al. 2015a) or modified materials like hybrid ceramics might be able to circumvent this issue and should, therefore, be evaluated for the restoration of one-piece zirconia oral implants.

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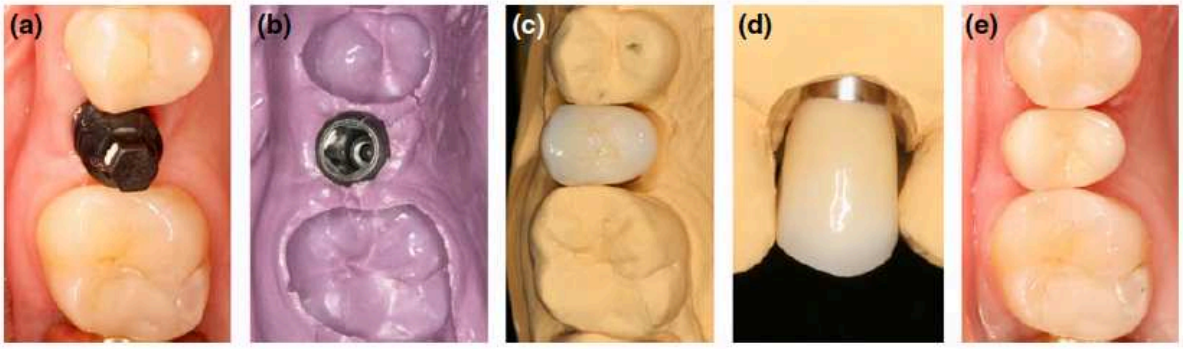

Figure 1

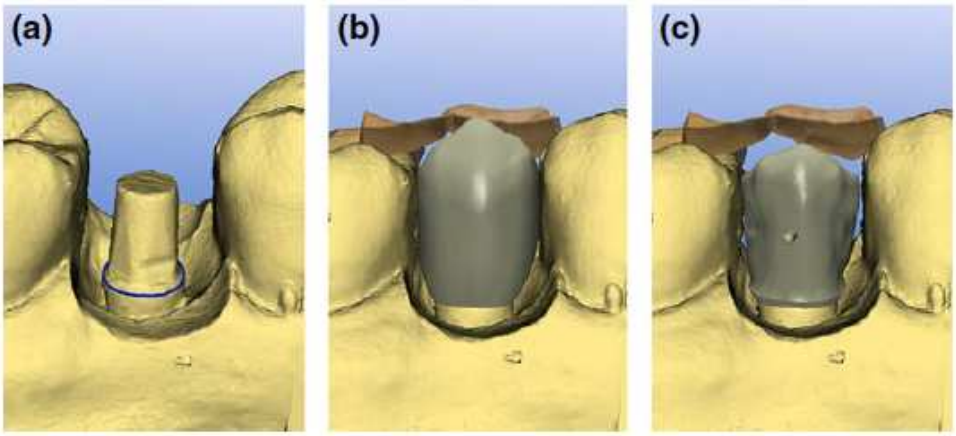

Figure 2

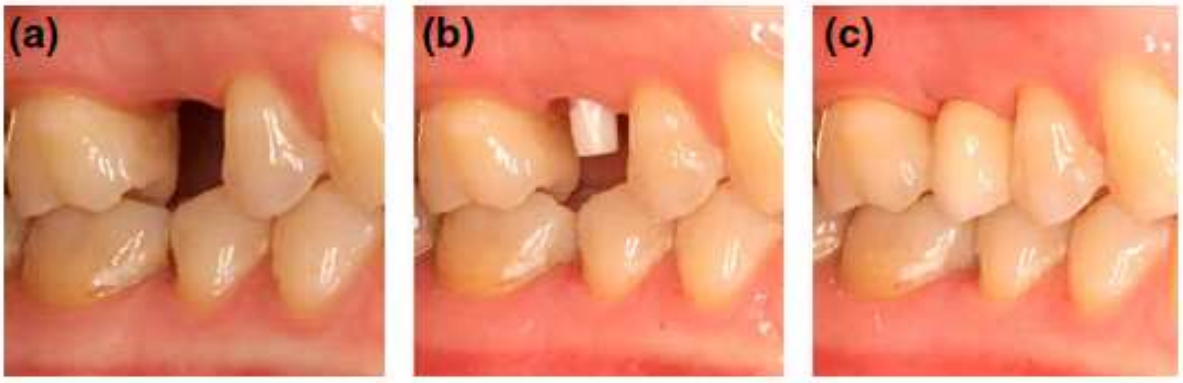

Figure 3

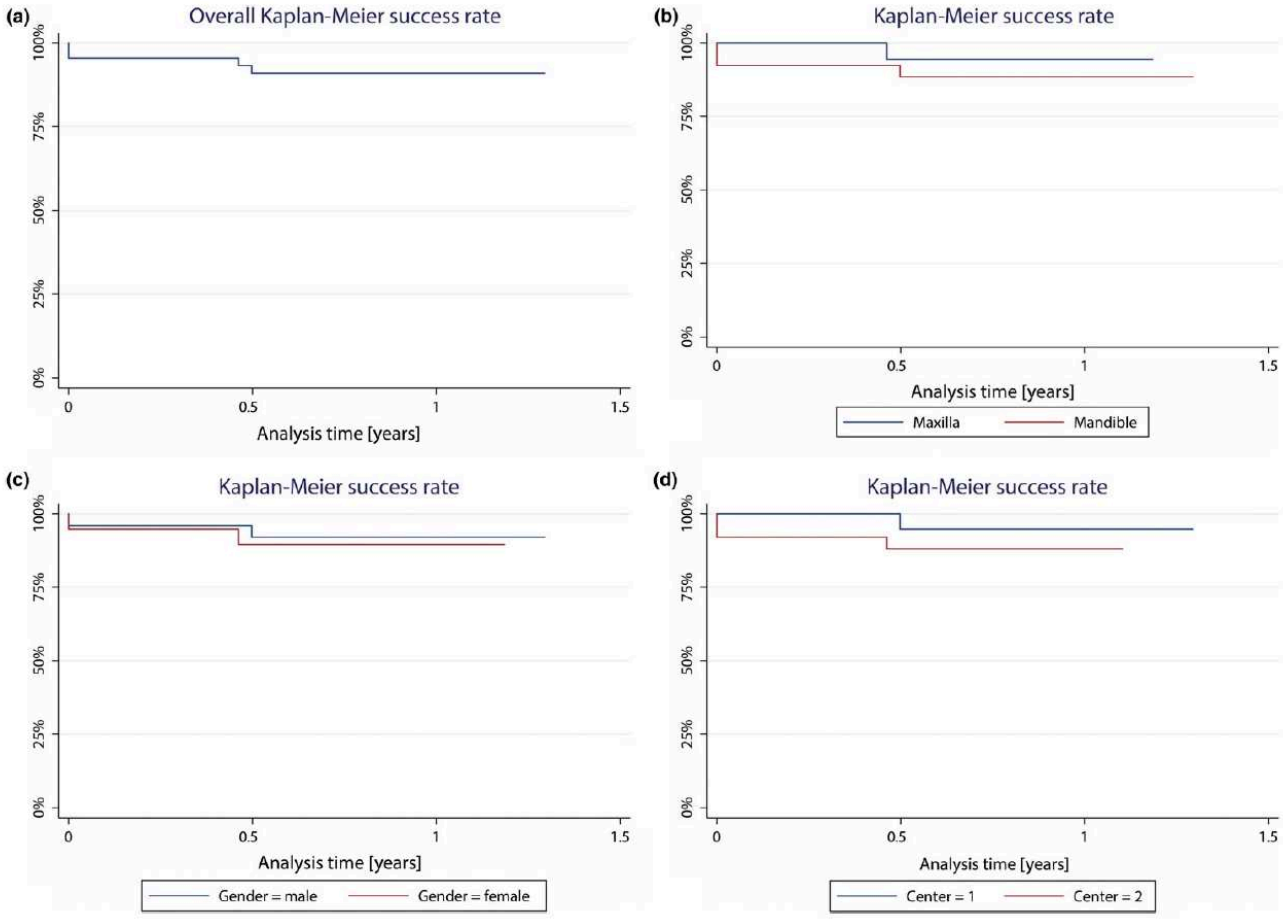
(a)
Overall Kaplan-Meier success rate
100%
75%
50%
25%
0%
0
0.5
1
1.5
Analysis time [years]
(b)
Kaplan-Meier success rate
100%
75%
50%
25%
0%
0
0.5
1
1.5
Analysis time [years]
Maxilla
Mandible
(c)
Kaplan-Meier success rate
100%
75%
50%
25%
0%
0
0.5
1
1.5
Analysis time [years]
Gender = male
Gender = female
(d)
Kaplan-Meier success rate
100%
75%
50%
25%
0%
0
0.5
1
1.5
Analysis time [years]
Center = 1
Center = 2

Figure 4

Jaw		Location		Gender		Center	
Maxilla	Mandible	Premolar	Molar	Female	Male	Freiburg	Zurich
18	26	17	27	19	25	19	25

Table 1

	Unit	In-Ceram YZ	VM9
Material		Yttria-stabilized TZP	Leucite-reinforced feldspathic porcelain
Main component		ZrO2	SiO2
Additional components (if >1WT %)		Y_2O_3, HfO_2	Al_2O_3, K_2O, Na_2O, CaO, B_2O_3, BaO,
CTE (20–500°C)	*[10^{-6}/K]*	10.5	8.8–9.2
Flexural strength	*[MPa]*	1200	102

Table 2

	Alpha (A)	Bravo (B)	Charlie (C)	Delta (D)
Fracture of framework	No fracture	–	–	Fracture (Loss of reconstruction)
Fracture of veneering ceramic	No fracture	Minor chipping (polishable)	Major chipping (up to framework)	Fracture (Loss of reconstruction)
Occlusal roughness	No roughness	Slight roughness (Ø < 2 mm)	Obvious roughness (Ø > 2 mm)	Reconstruction needs to be replaced
Marginal integrity	No visible or soundable gap	Marginal gap slightly soundable	Explorer penetrates a significant crevice	Reconstruction needs to be replaced
Contour of reconstruction	Perfectly contoured	Slightly under-/overcontoured	Pronounced under-/overcontouring	Reconstruction inacceptable
	Success	Success	Survival	Failure

Table 3

	Framework fracture	Chipping of veneering	Occlusal roughness	Marginal integrity	Contour
			n (Alpha/Bravo/Charlie/Delta)		
Delivery	44 (44/–/–/–)	44 (43/1/–/–)	44 (31/13/–/–)	44 (42/1/1–)	44 (19/24/1/–)
6-month follow-up	44 (44/–/–/–)	44 (39/4/1/–)	44 (22/21/1/–)	44 (41/2/1/–)	44 (23/20/1/–)
12-month follow-up	44 (44/–/–/–)	44 (36/7/1/–)	44 (18/26/–/–)	44 (40/3/1/–)	44 (19/24/1/–)

Table 4

		Jaw		Gender		Center	
	Overall	Maxilla	Mandible	Female	Male	Freiburg	Zurich
Survival	100	100	100	100	100	100	100
Success	90.9	94.4	88.5	89.5	92.0	94.7	88.0
95% CI	77.6–96.5	66.6–99.2	68.4–96.1	64.1–97.3	71.6–97.9	68.1–99.2	67.3–96.0
Significance*		*P* = 0.4996		*P* = 0.7656		*P* = 0.4301	

CI, confidence interval.
*log-rank test (significant results <0.05 are marked bold).

Table 5